THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ON-SITE GENERATION OF HALOGEN DISINFECTANTS USED IN PACKAGED DRINKING WATER TREATMENT SYSTEMS**
APPLICATION:	**ON-SITE GENERATION OF SODIUM HYPOCHLORITE**
TECHNOLOGY NAME:	**CLORTEC MODEL MC 100 SYSTEM**
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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by substantially accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholders groups which consist of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF) in cooperation with the EPA operates the Drinking Water Treatment Systems (DWTS) Pilot, one of 12 technology areas under ETV. The DWTS Pilot recently evaluated the performance of an on-site sodium hypochlorite generation (SHG) system used in package drinking water treatment system applications. This verification statement provides a summary of the test results for the ClorTec Model MC 100 System. Gannett Fleming Inc., an NSF-qualified field testing organization (FTO), performed the verification testing.

ABSTRACT

The EPA and NSF verified the performance of the ClorTec Model MC 100 System under the EPA's ETV program. The concentrated hypochlorite generator stream from the treatment system underwent a twice-daily analysis from March 8 to April 6, 2000. The chlorine analyses were conducted on site in United Water Pennsylvania's Hummelstown Water Treatment Plant (WTP) operators lab. The hypochlorite generator stream was analyzed using two methods of measuring total chlorine: *Standard Method* 4500-Cl F (EPA approved) and *Standard Method* 4500-Cl B. The average sodium hypochlorite concentration was 0.90% $\pm$ a standard deviation of 0.04% using *Standard Method* 4500-Cl B and 0.91% $\pm$ a standard deviation of 0.08% using *Standard Method* 4500-Cl F. The average sodium chloride concentration in the brine fed to the generator electrolytic cells during the verification testing was 3.53%, higher than ClorTec's specified value of 3.0%. The average DC current and voltage applied to the electrolytic cells during the ETV were 183 amps and 46 volts, respectively. ClorTec states that the amperage and voltage should be approximately 185 amps and 48 volts. No attempt was made to adjust the brine pump feed rate during the verification testing; it is factory set to deliver the concentrated brine (30% sodium chloride) to a softened side stream from the WTP finished water by a ratio of approximately ten parts water to one part brine prior to entering the generator. After the tenth day of testing, the chlorine concentration in the hypochlorite concentrate stream generally trended higher. This roughly correlated with a higher sodium chloride concentration.

TECHNOLOGY DESCRIPTION

On-site sodium hypochlorite generation systems for drinking water treatment are used in place of gas chlorine for primary and/or residual disinfection. The concentration of on-site generated sodium hypochlorite is typically less than 1%, sufficiently dilute so that the generation equipment does not require special handling or containment.

The process involves the application of a low-voltage DC current to a brine containing an approximate 3.0% sodium chloride concentration to generate a sodium hypochlorite concentration of approximately 0.8%. The generation process occurs inside clear four inch PVC tubes housing ten pairs of anode and cathode electrolytic plates. Current is applied to the electrolytic plates as the brine is pumped between the plates. The product generated from this reaction is sodium hypochlorite, plus the byproduct hydrogen. The cells are designed so that the hydrogen is readily separated from the sodium hypochlorite and vented to the outside.

The ClorTec Model MC 100 system is a modular system whose primary components consist of a power supply and rectifier, brine pump and electrolytic cells, and a Programmable Logic Controller (PLC)-based control panel. A brine saturator and day tank, water softener, sodium hypochlorite storage tanks and metering pumps are required in addition to the modular components. The system operates in the automatic batch mode based on setpoints entered into the PLC and liquid level signals transmitted back from the hypochlorite storage tanks. Only limited operator intervention is required.

The ClorTec Model MC 100 system is designed to produce up to 100 pounds per day of sodium hypochlorite as chlorine.

VERIFICATION TESTING DESCRIPTION

Test Site

The test site was United Water Pennsylvania's Hummelstown WTP. The water source for this plant is the Swatara Creek, a supply that can vary significantly in water quality, particularly turbidity, pH, alkalinity and hardness. The plant is a conventional WTP consisting of prechlorination, coagulation, clarification, granular media filtration and post chlorination. The pre- and post chlorination was supplied by the ClorTec Model MC 100 sodium hypochlorite generation system, permanently installed in the chemical room of the WTP. For monitoring purposes, the post chlorine feed point was selected as the ETV testing location.

Methods and Procedures

Measurement of the equipment's physical parameters occurred at least once daily during the ETV test period. This includes monitoring brine and sodium hypochlorite storage tank levels; feed water, brine dilution water and treated water flow rates; brine specific gravity; dilution water and brine temperatures; on-line analyzer sample flow rates; and rectifier amperage and voltage.

Softener waste stream flow rate and composition were also noted during the ETV test period.

All field analyses (i.e. pH, turbidity, chlorine residual, temperature and hydrogen sulfide) were conducted daily or, in the case of chlorine residual, twice daily, using bench test equipment in accordance with *Standard Methods for the Examination of Water and Wastewater*, 19th Ed. (1995).

All laboratory analyses were conducted by Microbac Laboratories (Microbac) using procedures from *Standard Methods* or EPA-approved methods. These analyses included the following inorganic parameters: alkalinity, ammonia nitrogen, UV_{254}, and true color, which were analyzed weekly and TDS, iron, manganese, chloride, bromide, and sodium, which were analyzed once during the test period. The disinfectant byproduct parameters analyzed by Microbac were chlorite, chlorate, total trihalomethanes (TTHMs) and haloacetic acids (HAA5). Samples were analyzed by Microbac five days per week for total coliform and heterotrophic plate counts.

Simulated Distribution System (SDS) Disinfectant Byproduct (DBP) Formation Testing was performed due to the fact that the ClorTec Model MC 100 system is used as the chlorine source for both primary disinfection and residual disinfection. The uniform formation conditions (UFC) of the EPA Information Collection Rule (ICR) were followed to estimate DBP formation in the distribution system, including TTHMs using EPA Method 524.2, HAA5 using *Standard Method* 6251B, and chlorite and chlorate, both using EPA Method 300.0.

VERIFICATION OF PERFORMANCE

System Operation

As previously indicated, the system operated in the auto batch mode. Generator operation was initiated based on the sodium hypochlorite level in the storage tanks. A 4-20 mA signal from level transmitters situated on top of each storage tank was sent to the PLC controller, which would activate the generator from standby if the levels in the hypochlorite storage tanks were below the previously entered setpoint. Generator operation was terminated based on sodium hypochlorite levels in the storage tanks reaching a previously entered high level setpoint. This mode of operation was effective during the ETV.

The number of SHG continuous hours of operation was primarily contingent on the WTP production rate, and varied from 3 hours to 25 hours with an average of 13 hours. The hypochlorite metering pumps, which are not an integral part of the ClorTec MC 100 system, typically had to be adjusted manually several times daily to account for this operating variable (there was no pacing system for the metering pumps).

No adjustments were made to the SHG dilution water flow, voltage or amperage during the ETV because these parameters and the brine specific gravity were within the ranges specified in the *ClorTec MC Operator Interface PLC Manual.*

Water Quality Results

The feed water turbidity was low due to coagulation/clarification/filtration of the raw water by the Hummelstown WTP, averaging 0.067 NTU during the verification testing. A free chlorine residual was maintained in the feed water, averaging 0.36 mg/l during the test period. Due to the high quality filtered water and the chlorine demand having been satisfied with prechlorination, the addition of post sodium hypochlorite provides a free available chlorine residual for achieving compliance with CT requirements under the EPA Surface Water Treatment Rule (SWTR), and provides a residual disinfectant throughout the distribution system.

Table 1 summarizes the results of on-site analytical testing for the 30 day verification test. The only change in water quality of any significance between the feed water and treated water was the concentration of chlorine. The addition of post sodium hypochlorite resulted in an average total chlorine concentration of 1.46 mg/l, an increase of 0.95 mg/l over feed water total chlorine level. As stated previously, the treatment prior to post sodium hypochlorite either removed or satisfied almost all of the chlorine demand, resulting in post chlorine being available largely as free chlorine. Temperature of the feed water averaged 11.4ºC. Hydrogen sulfide was not detected in the feed water; the minimum method detection level for hydrogen sulfide was 0.1 mg/l.

Table 1. On-Site Water Quality Analyses

	Feed Water (Filter Room Pumped Sample)						Treated Water (Finished Water - Lab Sink)							Hypochlorite Generator	
		Turbidity							Turbidity		FAC			TAC	
	Bench pH	Bench (NTU)	On-line (NTU)	Bench H_2S (mg/l)	On-line FAC (mg/l)	TAC FAS(1) (mg/l)	On-line pH	Bench pH	Bench (NTU)	On-line (NTU)	FAS(1) (mg/l)	On-line (mg/l)	TAC FAS(1) (mg/l)	FAS(1) (%)	Iodo(2) (%)
Mean	7.0	0.067	0.060	0	0.36	0.51	7.07	7.0	0.063	0.059	1.33	1.23	1.46	0.91	0.90
Minimum	6.2	0.040	0.040	0	0.01	0.08	6.80	6.5	0.046	0.040	1.05	1.00	1.00	0.80	0.78
Maximum	7.6	0.100	0.094	0	1.38	1.58	7.53	7.4	0.100	0.098	1.80	1.69	2.00	1.11	0.97
Std Dev	0.3	0.017	0.014	0	0.24	0.29	0.15	0.2	0.013	0.014	0.17	0.16	0.22	0.08	0.04
95% Conf	7.0±	0.067±	0.060±	N/A	0.36±	0.51±	7.07±	7.0±	0.063±	0.059±	1.33±	1.23±	1.46±	0.91±	0.90±
Interval	0.1	0.006	0.005		0.06	0.07	0.05	0.1	0.005	0.005	0.04	0.04	0.05	0.02	0.01

(1)FAS=Ferrous Ammonium Sulfate Titration (Standard Method 4500-Cl F)
(2)Iodo=Iodometric Titration (Standard Method 4500-Cl B)
FAC=Free Available Chlorine
TAC=Total Available Chlorine

Total Coliform, indicator bacteria for potential fecal contamination, and Heterotrophic Plate Count (HPC), a general indicator for total bacterial levels, were sampled five days per week for the test period. There were no positive indications for the presence of Total Coliform in either the feed water or treated water. HPC were detected in two feed water samples at 15 and 73 colony forming units (cfu)/ml and three treated water samples at 1, 58 and 71 cfu/ml. The dates that exhibited the two higher detections in the treated water corresponded to the sample dates of the two detections in the feed water. There is no indication in the WTP operating records or the ETV logbook of having lost hypochlorite feed during the sampling period when HPC were detected. The most likely reason for the detections was improper sampling procedures.

Six inorganic contaminants commonly found in water supplies were analyzed in the feed water and treated water once during the test period. Iron, manganese and bromide were below detection limits in both the feed water and treated water. TDS increased from 139 mg/l in the feed water to 147 mg/l in the treated water; sodium increased from 11.6 mg/l to 13.3 mg/l; and chloride increased from 23.8 mg/l to 27 mg/l. The TDS of the softener wastewater was much higher (7785 mg/l) than the feed water due to the removal and concentration of dissolved minerals in the softener treatment process. These increases in TDS, sodium and chloride are likely due to the addition of sodium hypochlorite to the feed water process.

The presence of ammonia can have a significant impact on disinfection due to the demand it places on chlorine. No ammonia was detected in either the feed water or treated water. The impact of feeding sodium hypochlorite on the alkalinity level was negligible, increasing it from an average of 28 mg/l as $CaCO_3$ to 30 mg/l as $CaCO_3$. Feed water and treated water alkalinity levels were, with the exception of one set of samples, the same.

UV_{254} and true color are parameters commonly used as indicators of the relative concentration of natural organic matter (NOM). The primary significance of NOM is as potential precursors for producing disinfection byproducts when combined with a disinfectant such as chlorine. The levels of UV_{254} and true color were relatively low, with no significant difference between the feed water and treated water.

Organic and inorganic disinfectant byproducts are presented on Table 2.

Table 2. Disinfectant Byproduct Analyses

Parameter	Feed Water (mg/l)	Treated Water (mg/l)
TTHM - Inst.	0.0140	0.0160
HAA5 - Inst.	0.0060	0.0187
TTHM - SDS	NT	0.0390
HAA5 - SDS	NT	0.0277
Chlorite - Inst	<0.02	<0.02
Chlorate - Inst	0.081	0.112
Chlorite - SDS	NT	<0.02
Chlorate - SDS	NT	0.262

Inst.=Instantaneous
SDS=Simulated Distribution System
NT=Not Tested

As indicated on Table 2, instantaneous analyses were conducted on both the feed water and treated water samples for TTHM and HAA5. DBP levels were anticipated to be higher in the treated water relative to the feed water due to the addition of post sodium hypochlorite and the additional contact time in the WTP finished water storage. As expected, TTHM and HAA5 levels were higher in the treated water, although only slightly for TTHM. In contrast, HAA5 levels increased by a factor of three.

A portion of the treated water sample was subject to UFC, as defined under the EPA ICR, for the purpose of producing SDS samples. These conditions resulted in a three-fold increase in TTHM and 30% increase in HAA5.

As with the organic DBP, instantaneous samples were collected for the feed and treated water inorganic DBP analyses. The promulgated Disinfectant/Disinfectant Byproduct Rule (D/DBPR) has an MCL of 0.8 mg/l for chlorite. Chlorite was not detected in either sample. Chlorate was detected in both the feed water and treated water. SDS conditions resulted in a doubling of the instantaneous chlorate level to 0.262 mg/l. There are presently no proposed regulations for chlorate.

Another disinfectant byproduct of ongoing concern using on-site generation of sodium hypochlorite is bromate. Bromate will be regulated under Stage 1 of the D/DBPR with an MCL of 0.01 mg/L. Although bromate was not a parameter required to be analyzed under the NSF on-site halogen production protocol, the precursor of bromate (bromide) was a required analysis. No bromide was detected in either the feed water or treated water. Bromide was also not detected in the chemical analysis of the sodium chloride used during the testing.

Feed Stock Consumption

Feed stock consisted of a solar grade salt and softened water used to dilute the salt into a brine solution. The salt is certified to be 99% pure sodium chloride, and contains a calcium concentration of less than 0.23%. The calcium concentration is important due to the scaling effect it can have on the generator electrode plates. Over the course of the 30 day test period, an average of 247 pounds of salt were used on a daily basis, producing an average of 842 gpd of 0.9% sodium hypochlorite.

Power Consumption

Power consumption was recorded daily for voltage and amperage, which was displayed locally on the power supply/rectifier, and remotely on the PLC cabinet LCD screen. The average daily DC current and voltage applied to the electrolytic cells was 183 amps and 46 volts, respectively.

Maintenance

There were a few items that required maintenance during the ETV, none of which directly involved the ClorTec MC 100 system but rather the softener, pump feed line and pH meter.

The hypochlorite generator electrodes had started to develop a scale formation by the end of the 30-day test, although the scaling had not developed to the point of loss in generator efficiency, requiring acid cleaning. (A loss in generator efficiency becomes evident when an increase in power is required to maintain the same level of concentrated chlorine).

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Inactivation of Microbiological Contaminants* dated August 9, 1999, the Verification Statement, and the Verification Report (NSF Report #00/16/EPADW395) are available from the following sources:

(NOTE: Appendices are not included in the Verification Report. Appendices are available from NSF upon request.)

1. Drinking Water Systems ETV Pilot Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)